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BIOLOGICAL WATER QUALITY MONITORING
NORTHWEST MONTANA
1978 - 1979

by

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Gary Ingman and Erich Weber

November 1979

State of Montana
Water Quality Bureau
Environmental Sciences Division
Department of Health and Environmental Sciences
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DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This report has been reviewed by the Montana Operations Office, U.S. Environmental Protection Agency, and approved for publication.

ABSTRACT

Values for 30 biologically-related water quality parameters were measured seasonally at 16 stations on 14 major streams in northwestern Montana from July 1978 to April 1979. Mean values for 16 key indicators were used to rank stations on the basis of biological conditions. A composite biological index, calculated by taking the average of seasonal diatom and macroinvertebrate diversity values, was used to evaluate water quality.

Streams of northwestern Montana were found to be significantly less productive and potentially more sensitive to acid mine drainage and heavy metals pollution than streams of southwestern Montana. All stations west of the Continental Divide had healthy benthic communities indicating little or no biological stress. Swiftcurrent Creek in the St. Mary River Drainage had marginal benthic diversity. Non-point source pollution was suspected and further investigation was advised.

Although most of the stations in the Northwest Loop had good water quality, many smaller streams in northwest Montana, which were not sampled, are known to suffer from polluting land use practices. However, most of these small tributary streams, particularly those originating in mountainous areas, probably have water quality equal or superior to the quality of waters surveyed in the Northwest Loop.

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PREFACE

> The importance of long term monitors is evident when one considers the ecology of our biosphere, because it is being increasingly manipulated and polluted by the civilization of man. This is due to the increased population which results in an increased demand for materials for life and for habitation... (Patrick, 1977)

An interim goal of the 1972 amendments to the Federal Water Pollution Control Act is to have, wherever attainable, fishable and swimmable water by July 1, 1983. The benefits realized by achieving this goal will be substantial, since water quality that permits fishing and swimming is also suitable for most other beneficial uses.

To reach the 1983 goal, the basic biological communities and processes that allow fishing and swimming must be maintained in a healthy balance. For example, algae must not become a nuisance and the small aquatic animals that fish eat must be present in variety and abundance. Until recently, basic biological processes such as photosynthesis, and aquatic life forms lower than fish, had been given little consideration in water quality management, yet these processes and life forms are basic to the integrity of the entire aquatic ecosystem. Any effects here on the "ground floor" likely will have repercussions on up the food chain.

Chemical and physical properties of water affect living organisms in ways we are just beginning to understand. Aquatic organisms are capable of intergrating the many and diverse factors of their environment and of expressing their combined effect in terms of growth, reproductive success, and the resulting community diversity. Aquatic organisms vary in their sensitivity to pollutants, hence some of the more sensitive and tolerant taxa have become useful as water quality indicators. Lower life forms are particularly useful as indicators because they are almost always present in statistically significant numbers.

To maintain water quality for fish and aquatic life is public policy of the State of Montana [Sec. 75-5-101(1), M.C.A. 1979]. Pollution is defined in part as "...contamination, or other alteration of the physical, chemical, or biological properties of any state water..." [Sec. 75-5-103(5), M.C.A. 1979]. To measure our success at protecting aquatic life and controlling pollution we need a good yardstick. What is a better yardstick than the biological organisms and processes themselves? Yet there has been no comprehensive, systematic, and continuing biological monitoring to date in Montana.

The Montana Biological Monitoring Program is designed to help fill this need. The program consists of a network of stations, a battery of parameters, and a sampling strategy.

The network includes 85 stations on 59 streams statewide, with at least one station in each of the state's major drainage basins. Stations were located mostly on the larger rivers and streams under the assumption that these sites would most accurately reflect water quality conditions basin-wide. Stations are grouped geographically into five loops, each with 16 to 20 stations. Thirty-three of the sampling sites are located at or near U.S.G.S. water quality stations and 10 conform to U.S.G.S. NASQAN (National Stream Quality Accounting Network) stations. Streams and stations in the state biological monitoring network are listed in Appendix A.

Data are gathered in seven biologically-related areas: streamflow, common ions (including specific conductance and total alkalinity), algal nutrients (nitrogen and phosphorus), algal growth potential (algal assay), instream periphyton production, periphyton community structure, and macroinvertebrate community structure.

Stations are monitored seasonally during periods of stable flow, once in summer (July-August), once in fall (September-October), and once in spring (March-April). Ice and high flows have proven to be serious impediments to biological sampling. Consequently, sampling in winter and during peak snowmelt will not be pursued, even though these are times of stress for aquatic organisms.

Beginning in 1980, when the seasonal baseline assessment will have been completed for all 85 stations, the program will be streamlined for year-to-year operation: Stations will be sampled once annually in summer or fall to permit the evaluation of trends. Only long-term biological monitors--periphyton and macroinvertebrate community structure--will be examined. (These two features are at the heart of the Montana Biological Monitoring Program). An appropriate biological index will be adopted. Certain stations may be dropped and others added. Obviously, the program is not designed for rapid detection of acute problems but rather for evaluation of chronic, long-term trends.

Comments are welcome, especially now when the program is new. All stations, parameters, and procedures are on trial and subject to continuing evaluation. If we have overlooked a stream of particular interest to you, please let us know and give us your reasons why it should be included in the network. We would also like your comments on the overall usefulness of the program to you. It is hoped that these reports will be more than just internal management documents, and that they will aid resource managers, municipalities, industries, and the public in assessing water quality conditions and trends in their area.

INTRODUCTION

This is the third in a continuing series of reports on biological conditions in Montana rivers and streams.

The Northwest Loop includes some of the purest waters in America; concentrations of dissolved chemicals are the lowest in Montana. The region is largely forested, with agriculture restricted to the mostly narrow valley bottoms. It contains one of the fastest growing areas of the state--the Flathead Valley. Water quality problems can be grouped into three categories: excess sediment from mining, forestry and agricultural practices; nutrients and coliforms from livestock and the rapidly expanding human population; and flow, temperature and gas problems associated with large hydroelectric dams (Water Quality Bureau, 1976).

Stream stations covered in this report are listed in Table 1, along with station locations and abbreviations used in subsequent tables. The sixteen stations in the Northwest Loop are distributed among four drainage basins as follows: Flathead--7, Clark Fork--5, Kootenai--3, and St. Mary--1.

Parameters covered in this report are listed in Table 2. Tests for all parameters except common ions and algal growth potential (algal assays) were run seasonally, in July-August 1978 (summer), October 1978 (fall), and March-April 1979 (spring). Common ions and algal growth potential were determined for the summer trip only.

The Northwest Loop is scheduled to be run again in summer 1980, along with the remaining four loops. At that time changes in values of the different parameters can be compared and evaluation of long-term trends in water quality can begin. Henceforth, the composite biological water quality index presented at the end of this report (See "SUMMARY AND CONCLUSIONS") will be used to simplify the rating of streams and the evaluation of trends.

Table 1. Stream stations covered in this report

Code	Description	Location
Bitterroot River	Bitterroot River near mouth	T13N R20W 27DDD
Clark Fork River/ Bonner	Clark Fork River below Bonner Dam	T13N R18W 20AAC
Clark Fork River/ Huson	Clark Fork River at Huson RR Bridge	T15N R22W 26DBD
Clearwater River	Clearwater River near mouth	T15N R14W 33BBB
Fisher River	Fisher River at mouth	T30N R29W 21BDD
Flathead River/ Kalispell	Flathead River near Kalispell	T28N R21W 2BCA
Flathead River/Perma	Flathead River near mouth	T18N R24W 5DDC
Lake Creek	Lake Creek near mouth near Troy	T30N R33W 8BBC
Little Blackfoot River	Little Blackfoot River at Avon	T10N R8W 27BDA
Middle Fork Flathead River	Middle Fork Flathead River near mouth	T32N R19W 34ACC
North Fork Flathead River	North Fork Flathead River near mouth	T32N R20W 35BCA
Stillwater River	Stillwater River near mouth at Kalispell	T28N R21W 8BBB
Swan River	Swan River near mouth	T26N R19W 11CDB
Swiftcurrent Creek	Swiftcurrent Creek near Babb	T36N R14W 28DDD
Whitefish River	Whitefish River near mouth near Kalispell	T29N R21W 8ADC
Yaak River	Yaak River near mouth	T32N R34W 5DDA

Table 2. Parameters covered in this report

Instantaneous Streamflow (m^3/sec)

Common Ions
- Cation Ratio: Ca:Mg:Na
- Anion Ratio: HCO_3: SO_4:Cl
- Specific Conductance (micromhos @25 C)
- Total Alkalinity (mg/l $CaCO_3$)

Algal Nutrients
- NO_2+NO_3-N; NH_3-N; Kjeldahl-N; PO_4-P; Total P (all in mg/l)
- Total Soluble Inorganic Nitrogen (NO_2+NO_3-N plus NH_3-N): PO_4-P Ratio
- TSIN and Total P as % of recommended maximum instream levels (0.35 mg/l TSIN and 0.05 mg/l Total P)

Algal Assay
- Control
  Mean Maximum Standing Crop (MMSC) (mg/l)
  Statistical significance of MMSC
- Nutrient Spike
  Mean Maximum Standing Crop (MMSC) (mg/l)
  Statistical significance of MMSC
- Nutrient Spike + EDTA
  Mean Maximum Standing Crop (MMSC) (mg/l)
  Statistical significance of MMSC

Periphyton Production
- Chlorophyll a Accrual (mg/m^2/day)
- Biomass Accrual (mg/m^2/day)
- Autotrophic Index
- Chlorophyll a/Pheophytin a Ratio ($OD663_b/OD663_a$)
- Carotene/Chlorophyll Ratio (OD430/OD663)

Periphyton Community Structure
- Rank of diatoms relative to other algae
- Percent Relative Abundance (PRA) of Major Diatom Species
- PRA *Achnanthes* species
- PRA *Nitzschia* species
- Number of Diatom Species
- Diatom Species Diversity ($\bar{d}$)

Macroinvertebrate Community Structure
- Mean PRA Major Macroinvertebrate Orders
- Mean PRA Tolerant, Facultative and Intolerant Macroinvertebrates
- Number of Macroinvertebrate Genera
- Macroinvertebrate Genus Diversity ($\bar{d}$)
- Number of Organisms collected

RATIONALE, METHODS, RESULTS, AND INTERPRETATIONS

STREAMFLOW

Rationale

Accurate measurements of streamflow are essential for calculating loads of dissolved constituents, particularly nutrients. Many aquatic organisms have specific instream flow requirements for various activities. Exceptionally high and low flows--overbank flooding and complete dewatering in the extremes--are rather traumatic events for a river and its aquatic life. Periodic streamflow measurements also circumscribe a stream's size, which in turn dictates the nature of the aquatic community it can support.

Methods

Flow rates at the Lake Creek and Little Blackfoot River stations were measured with a Pygmy Gurley current meter. A straight section of stream with a uniform cross-section and a smooth bottom was chosen whenever available. A measuring tape was stretched across the channel and depths and velocities were recorded at selected points such that no more than 10 percent of the total discharge fell between two consecutive points. Total instantaneous discharge was then estimated by summing flows for each of the measured subsections.

Where biological monitoring and U.S.G.S. gaging stations coincide, streamflow measurements were taken from the records of the U. S. Geological Survey, Water Resources Division, Helena. Estimated flows for the Clark Fork River/Huson and Swiftcurrent Creek stations were measured at U.S.G.S. gaging stations located short distances upstream from these sites: Clark Fork River below Missoula and Swiftcurrent Creek at Sherburne, respectively. Flow in the Bitterroot River was estimated by taking the difference between flows at the two Clark Fork River stations. Flows at the two mainstem Flathead River sites could not be estimated accurately because of the considerable distances between the biological monitoring stations and the nearest U.S.G.S. gaging stations.

Results

Instantaneous streamflows are presented in Table 3.

Interpretation

Mean instantaneous streamflow ranged from 2.56 m^3/sec in the Little Blackfoot River to 116.28 m^3/sec in the Clark Fork River at Huson. Mainstem Flathead River flows probably were of the same order of magnitude as Clark Fork River flows. The mean of all summer flows was nearly twice the mean of all fall flows. Spring flows averaged even less than fall flows, but were taken at a time in late March when snowmelt had not begun in most drainages.

Table 3. Instantaneous streamflow (m^3/sec)

Station	Summer	Fall	Spring	Mean
Bitterroot River	45.02(E)	28.88(E)	35.11(E)	36.34(E)
Clark Fork River/ Bonner	102.78	61.16	75.88	79.94
Clark Fork River/ Huson	147.80(E)	90.04(E)	110.99(E)	116.28(E)
Clearwater River	5.80	2.12	3.00	3.64
Fisher River	5.66	3.31	17.72	8.90
Flathead River/ Kalispell	FNM	FNM	FNM	FNM
Flathead River/Perma	FNM	FNM	FNM	FNM
Lake Creek	8.27	FNM	7.45	7.86
Little Blackfoot River	3.31	2.25	2.12	2.56
Middle Fork Flathead River	80.98	33.41	13.93	42.77
North Fork Flathead River	84.94	38.22	23.19	48.78
Stillwater River	10.05	4.25	1.78	5.36
Swan River	46.43	18.04	7.90	24.12
Swiftcurrent Creek	13.70(E)	13.28(E)	0.34(E)	9.11(E)
Whitefish River	6.17	2.49	2.27	3.64
Yaak River	11.04	4.62	11.18	8.95
Mean	40.85	23.24	22.35	28.95

FNM: Flow not measured
(E): Estimate

COMMON IONS

Rationale

Common ions are the basic ingredients of the chemical "soup" in which aquatic organisms live. Their relative proportions often dictate the nature of plant and animal communities inhabiting surface waters. Specific conductance is a measure of osmotic stress on organisms -- both aquatic and terrestrial -- that live in, drink off, or are irrigated by the water in question. Total alkalinity measures the acid-neutralizing capacity of water. It is thus an indicator of a water's resiliency to acid rainfall and mine drainage. It is also roughly proportional to a water's basic fertility or productivity.

Methods

Unpreserved and unfiltered grab samples were collected in one liter plastic bottles and transported under ice back to the laboratory. Analytical procedures followed the American Public Health Association (1971; 1975) or the U. S. Environmental Protection Agency (1974). Specific conductance was measured with a Wheatstone Bridge. Calcium and magnesium were measured by EDTA titration. Sodium was measured by atomic absorption. Bicarbonate and total alkalinity were measured by the automated methyl orange method or by titration with 0.02N H_2SO_4 to a pH 4.5 endpoint. Sulfate was determined by the automated turbidimetric method. Chloride was measured by the automated mercuric thiocyanate method or by mercuric nitrate titration.

Results

Common ion ratios and conductance and alkalinity values for the summer 1978 sampling run are presented in Table 4.

Interpretation

Waters of the Northwest Loop were of consistently high quality in terms of dissolved minerals. Consequently, they are suitable for most beneficial uses, unless other harmful constituents are present to excess. Maximum conductance and alkalinity values among the Northwest Loop stations were lower than average values for all stations of the Southwest Loop and lower than minimum values among stations of the Northcentral Loop (Bahls *et al*., 1979; Ingman *et al*., 1979). Streams and rivers of the Northwest Loop have soft to medium hard, calcium/magnesium/bicarbonate waters. The low alkalinities in this part of the state may help to explain why these waters are relatively infertile when compared to waters with similar thermal and substrate characteristics in central and southwestern Montana. In addition, the low buffering capacity makes these waters among the most sensitive in the state to heavy metals pollution.

Table 4. Specific Condutance (μmhos @25 C), Total Alkalinity ($mg/l CaCO_3$), and common ion ratios (as meq/l).

Station	Specific Conductance	Total Alkalinity	Ca:Mg:Na	$HCO_3:SO_4:Cl$
Bitterroot River	109	51	4:2:1	20:1:1
Clark Fork River/ Bonner	276	115	8:4:1	44:13:1
Clark Fork River/ Huson	238	95	6:3:1	22:5:1
Clearwater River	120	52	13:8:1	45:2:1
Fisher River	180	88	7:4:1	21:1:0
Flathead River/ Kalispell	159	78	22:11:1	195:11:1
Flathead River/Perma	168	89	19:8:1	127:4:1
Lake Creek	74	36	12:5:1	31:1:1
Little Blackfoot River	227	103	7:3:1	46:7:1
Middle Fork Flathead River	164	77	24:11:1	192:9:1
North Fork Flathead River	170	78	31:11:1	195:13:1
Stillwater River	216	112	17:7:1	112:1:1
Swan River	142	69	30:13:1	125:2:1
Swiftcurrent Creek	126	53	19:14:1	96:6:1
Whitefish River	163	80	18:8:1	94:2:1
Yaak River	105	54	8:3:1	135:4:1
Mean	165	77		

ALGAL NUTRIENTS

Rationale

Nitrogen and phosphorus are the two elements most commonly limiting algal growth in lakes and streams. Phosphorus is usually limiting in lakes because many common lake algae can use atomspheric nitrogen. These nitrogen-fixing algae are not common in streams, therefore nitrogen is more often a limiting nutrient in flowing water. Only the soluble inorganic forms of these two nutrients -- nitrate, nitrite and ammonia nitrogen and orthophosphate -- are readily available for plant uptake. The sum of the soluble inorganic nitrogen fractions is called total soluble inorganic nitrogen or TSIN.

Some indication of whether nitrogen or phosphorus is growth limiting may be obtained by determining the weight ratio of the appropriate forms of nitrogen and phosphorus found in a river, and comparing that with the stoichiometric ratio required for growth (Zison et al., 1977). Specifically, let

$$R = \frac{[TSIN]}{[PO_4\text{-}P]}$$

where [TSIN] equals the concentration of total soluble inorganic nitrogen as N in mg/l and $[PO_4\text{-}P]$ equals the concentration of phosphate as P in mg/l. If R is greater than 10, phosphorus is more likely limiting than nitrogen. If R is less than 5, nitrogen is more likely limiting than phosphorus. If R is less than 10 but greater than 5, it's a tossup as to which one is limiting.

Nuisance growths of aquatic plants in streams usually can be avoided if total phosphorus is kept below 0.05 mg/l (Mackenthun, 1969) and if TSIN remains less than 0.35 mg/l (Muller, 1953). The total phosphorus criterion is particularly applicable if the stream enters a standing body of water, which is eventually true of most streams in the Northwest Loop. When instream total phosphorus and TSIN values are computed as percentages of these critical levels, nuisance growths can be expected where both total phosphorus and TSIN are significantly greater than 100 percent, other factors being amenable to algae growth.

Methods

Unfiltered grab samples were collected in separate one liter plastic bottles, each preserved with 4 ml of $HgCl_2$ and transported under ice back to the laboratory. Analytical procedures followed the American Public Health Association (1971; 1975) or the U. S. Environmental Protection Agency (1974). Orthophosphate was measured by automated ascorbic acid reduction. Total phosphorus was determined by persulfate digestion followed by automated ascorbic acid reduction. Nitrate plus nitrite nitrogen was measured by the automated cadmium reduction method. Ammonia was measured by the automated phenolate method. Total Kjeldahl nitrogen was determined by manual digestion followed by the automated phenolate procedure.

Results

Measured algal nutrient levels for the 1978-1979 sampling seasons are listed in Appendixes B through F. TSIN: PO_4-P ratios are presented in Table 5. Tables 6 and 7 give instream TSIN and total phosphorus values as percentages of maximum recommended instream concentrations.

Interpretation

As with streams of the Southwest Loop (Bahls et al., 1979), nutrient ratios were variable from season to season, with nitrogen generally more available in fall than in spring or summer. Based on data averaged over all three seasons, seven sites are phosphorus limited: Lake and Swiftcurrent creeks and the Clearwater, Flathead (Kalispell), Little Blackfoot, Middle Fork Flathead, and Swan rivers. (However, the Clearwater, Little Blackfoot, and Swan rivers appear to be nitrogen limited during the critical summer algae growing season). By the same token, six stations appear to be nitrogen limited: both Clark Fork River stations, the Fisher, Flathead (Perma), Stillwater, and Whitefish rivers. The remaining three sites had intermediate mean values ($10>R>5$), but all three tend to be nitrogen limited during the summer season.

Only the Whitefish River had both nitrogen and phosphorus levels significantly in excess of recommended instream concentrations. The Whitefish is therefore capable of producing nuisance algal growths at certain times of the year, assuming other growth factors are favorable. The Little Blackfoot River had excess nitrogen only, while the Clark Fork and Stillwater rivers had excess phosphorus only. These waters could produce nuisance algal growths given substantial inputs of the nutrient in short supply.

Table 5. Ratio of total soluble inorganic nitrogen (NO_2+NO_3-N plus NH_3-N) to phosphate phosphorus (PO_4 as mg/l P)

Station	Summer	Fall	Spring	Mean*
Bitterroot River	5:1	14:1	6:1	7:1
Clark Fork River/ Bonner	2:1	8:1	3:1	3:1
Clark Fork River/ Huson	2:1	4:1	5:1	4:1
Clearwater River	2:1	25:1	> 20:1	11:1
Fisher River	2:1	> 20:1	3:1	3:1
Flathead River/ Kalispell	13:1	10:1	> 20:1	16:1
Flathead River/Perma	6:1	20:1	2:1	4:1
Lake Creek	8:1	40:1	> 50:1	22:1
Little Blackfoot River	1:2	81:1	1:1	18:1
Middle Fork Flathead River	35:1	> 90:1	> 140:1	93:1
North Fork Flathead River	< 5:1	> 10:1	> 20:1	8:1
Stillwater River	2:1	10:1	2:1	2:1
Swan River	< 5:1	> 10:1	> 30:1	10:1
Swiftcurrent Creek	18:1	20:1	> 80:1	21:1
Whitefish River	1:1	1:2	4:1	1:1
Yaak River	< 5:1	> 20:1	> 20:1	8:1
Mean*	4:1	29:1	5:1	4:1

*Assumes concentrations less than 0.01 mg/l TSIN and 0.001 mg/l phosphate phosphorus equal zero

Table 6. Total soluble inorganic nitrogen (NO_2+NO_3-N plus NH_3-N) as a percentage of the recommended maximum instream concentration (0.35 mg/l)

Station	Summer	Fall	Spring	Mean*
Bitterroot River	14	20	29	21
Clark Fork River/ Bonner	6	9	37	17
Clark Fork River/ Huson	9	14	57	27
Clearwater River	3	14	6	8
Fisher River	3	6	17	9
Flathead River/ Kalispell	14	3	6	8
Flathead River/Perma	9	6	9	8
Lake Creek	11	11	14	12
Little Blackfoot River	3	323	11	112
Middle Fork Flathead River	40	26	40	35
North Fork Flathead River	<6	3	6	3
Stillwater River	3	3	43	16
Swan River	<6	3	9	4
Swiftcurrent Creek	26	6	23	18
Whitefish River	3	3	106	37
Yaak River	<6	6	6	4
Mean*	9	29	23	21

*Assumes concentations less than 0.01 mg/l equal zero

Table 7. Total phosphorus as a percentage of the recommended maximum instreamconcentration (0.05 mg/l)

Station	Summer	Fall	Spring	Mean*
Bitterroot River	60	80	40	60
Clark Fork River/ Bonner	80	80	100	87
Clark Fork River/ Huson	80	100	120	100
Clearwater River	60	40	20	40
Fisher River	40	< 20	60	33
Flathead River/ Kalispell	20	20	< 20	13
Flathead River/Perma	40	20	80	47
Lake Creek	20	100	20	47
Little Blackfoot River	60	60	80	67
Middle Fork Flathead River	20	< 20	< 20	7
North Fork Flathead River	40	80	< 20	40
Stillwater River	40	20	180	80
Swan River	20	20	< 20	13
Swiftcurrent Creek	60	< 20	< 20	20
Whitefish River	60	60	220	113
Yaak River	20	< 20	< 20	7
Mean*	45	43	58	48

*Assumes concentration less than 0.01 mg/l equal zero

ALGAL ASSAY

Rationale

The algal assay is based on Liebig's law of the minimum, which states that "growth is limited by the substance that is present in minimal quantity with respect to the needs of the organism" (U.S.E.P.A., 1971). Algal assays are used in the biological monitoring program for the following purposes: 1) to determine the algae growing potential of stream water; 2) to determine the algae growing potential of stream water after introducing nutrients that would be present in a municipal wastewater discharge; and 3) to determine whether various constituents in stream water, usually heavy metals, are toxic or inhibitory to algae. Although most heavy metals in high concentrations are toxic to algae, many, including zinc and copper, are essential in trace amounts to algal growth (Lewin, 1962).

Methods

Algal assays were conducted following "bottle test" procedures published by the U. S. Environmental Protection Agency (Miller et al., 1978). The unicellular green alga *Selenastrum capricornutum* Printz was used as the test alga. Combined nutrient spikes consisted of 0.10 mg/l P plus 1.00 mg/l N. A combined nutrient spike plus a chelating agent (1.00 mg/l Na_2EDTA) was used to test for algal growth inhibition by heavy metals. (Na_2EDTA may also effect an increase in algal production by providing some additional nitrogen and by increasing the mobility of essential metals such as iron and manganese.) Three replicates were run on each treatment, i.e., control, combined nutrient spike, and combined nutrient spike plus Na_2EDTA. Maximum standing crop was measured and reported in terms of mg/l dry weight, averaged over the three replicates. Theoretical maximum standing crop (TMSC) was determined by multiplying measured ortho-P and TSIN values by the appropriate production coefficient (430 and 38, respectively) and by taking the lesser of the two resulting values. Statistical reliability of mean maximum standing crop (MMSC) as compared to theoretical maximum standing crop (TMSC) was determined from coefficient of variance criteria presented by Miller et al. (1978):

$\pm$ 50% for TMSC $<$ 1.00 mg/l

$\pm$ 30% for TMSC $>$ 1.00 but $<$ 3.00 mg/l

$\pm$ 20% for TMSC $>$ 3.00 but $<$ 10.00 mg/l

$\pm$ 10% for TMSC $>$ 10.00 mg/l

Low MMSC values that are significantly different could be due to: 1) micronutrients limiting; 2) something toxic or inhibitory in the water sample; and/or 3) nutrients incorrectly overestimated. High values that are significantly different could be the result of incorrectly underestimating nutrients available to the algae.

Results

Algal assay results for summer 1978 are presented in Table 8.

Interpretation

Among stations of the Northwest Loop, higher than average algal growth was recorded on the Clark Fork River at Huson, on the Flathead River at Perma, and on the Little Blackfoot River at Avon. Nevertheless, the average control value for all Northwest Loop stations (0.99 mg/l) was significantly lower than the average summer control value for all Southwest Loop stations in 1977 (4.24 mg/l), reflecting the generally lower productivity of waters in northwestern Montana.

All of the waters of the Northwest Loop but three exhibited a significant increase in algal growth when excess nitrogen and phosphorus were provided. The three exceptions--Swan River, Swiftcurrent Creek, and Whitefish River--all responded positively to the addition of Na_2EDTA, indicating that either micronutrients (most likely Fe or Mn) were limiting when macronutrients (N and P) were present to excess or that one or more of the heavy metals were inhibiting growth in the water sample. The Yaak River sample responded predictably to the combined nutrient spike, but growth dropped considerably with the addition of Na_2EDTA. This effect may have been caused by Na_2EDTA chelating essential micronutrients and making them unavailable to the algae.

Table 8. Algal assay results, summer 1978

Station	Control		Nutrient Spike		Nutrient Spike + EDTA	
	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?
Bitterroot River	0.26	Yes-Low	60.22	Yes-High	54.81	Yes-High
Clark Fork River/ Bonner	0.20	Yes-Low	71.28	Yes-High	82.68	Yes-High
Clark Fork River/ Huson	5.01	No	67.34	Yes-High	74.77	Yes-High
Clearwater River	0.19	No	64.73	Yes-High	76.91	Yes-High
Fisher River	0.18	Yes-Low	71.28	Yes-High	82.68	Yes-High
Flathead River/ Kalispell	0.97	No	62.05	Yes-High	83.31	Yes-High
Flathead River/Perma	3.51	No	63.68	Yes-High	73.81	Yes-High
Lake Creek	0.25	No	72.03	Yes-High	78.54	Yes-High
Little Blackfoot River	3.14	Yes-High	77.50	Yes-High	72.17	Yes-High
Middle Fork Flathead River	0.15	Yes-Low	76.26	Yes-High	71.59	Yes-High
North Fork Flathead River	0.36	No	65.15	Yes-High	72.71	Yes-High
Stillwater River	0.43	No	64.11	Yes-High	59.85	Yes-High
Swan River	0.28	No	27.25	Yes-Low	73.26	Yes-High
Swiftcurrent Creek	0.24	Yes-Low	22.18	Yes-Low	79.76	Yes-High
Whitefish River	0.40	Yes-Low	1.83	Yes-Low	80.64	Yes-High
Yaak River	0.21	No	50.99	No	4.84	Yes-Low
Mean	0.99		57.37		70.15	

PERIPHYTON PRODUCTION

Rationale

Periphyton is the community of plants and animals, most of them microscopic, living attached to or in close proximity of the stream bottom. In terms of primary production -- converting solar energy to plant biomass -- it is the most important community in the majority of Montana streams.

Measuring the growth of periphyton organisms on artificial substrates placed in a stream is one method of estimating the productive potential of the stream. The two parameters most commonly measured are chlorophyll a (the most significant photosynthetic pigment) and ash-free weight or biomass. Measurements of these parameters have been made on a great variety of surface waters worldwide and in Montana. Chlorophyll accrual rates in some Montana streams have been summarized by Klarich (1976). An assessment of a stream's trophic status can be made by comparing its rate of accrual to rates in other waters known to be oligotrophic, mesotrophic or eutrophic.

The autotrophic index (AI) is the ratio of biomass to chlorophyll a. Chlorophyll a usually contributes from 1 to 2 percent of algal dry weight, resulting in AI values of 50 to 100 in pure algal cultures. As a stream is enriched with organic compounds the proportion of consuming, non-chlorophyll bearing organisms increases and the fraction of autotrophic, chlorophyll bearing organisms (algae) decreases. Unpolluted stream AI values normally range from 50 to 200. Much larger AI values indicate poor water quality (A.P.H.A., 1975).

The amount of pheophytin a in a periphyton sample relative to the amount of chlorophyll a is an indicator of the physiological condition of the algae. Pheophytin a is derived from chlorophyll a upon breakdown and loss of magnesium ion. Acidification in the laboratory has the same effect. Acidification of a solution of pure chlorophyll a results in a 40 percent reduction in optical density, yielding a before/after acidification ratio of about 1.7. Field samples with a ratio of 1.7 are considered to contain little if any pheophytin a and to be in excellent physiological condition. Solutions of pure pheophytin show no reduction in optical density upon acidification and have a before/after ratio of 1.0. Thus, mixtures of chlorophyll a and pheophytin a have optical density ratios ranging from 1.0 to 1.7 (A.P.H.A., 1975).

The ratio of yellow pigment (carotene) to green pigment (chlorophyll) in a sample of mixed algae can be used as an index of community stability and productivity (Margalef, 1969). In young, vigorously growing algal communities the green photosynthetic pigment chlorophyll a predominates and the yellow to green optical density ratio is low, usually about 2. As the community ages and becomes more diversified, yellow pigments predominate and the yellow to green ratio increases to 3 or greater (Odum, 1963).

Methods

Artificial substrates (glass microscope slides) were used to measure the accrual of periphyton pigments and biomass. The slides were placed in a plastic carriage (Periphytometer II) produced by Design Alliance, Inc.

of Cincinnati, Ohio. The carriage and slides ensemble was tied to a cement cinder block, which served as an anchor. The sampling device was placed in water of moderate current velocity (0.1 to 0.5 m/sec) and moderate depth (0.3 to 1.0 m) such that the slides were oriented with their surfaces perpendicular to the direction of flow. The slides were exposed from 13 to 28 days depending on season, water temperature, and inherent productivity.

Upon retrieval, the slides were removed from the carriage and immediately placed into light-proof slide boxes. The boxes were labeled and transferred to the laboratory on ice. On arrival at the lab, the boxes were placed in a freezer for at least 24 hours to enhance cell lysis.

Pigment extraction and measurement were then performed according to the American Public Health Association (1975) with the following procedural exceptions. Periphyton was scraped into 50 ml, foil-wrapped centrifuge tubes. For each slide scraped, 10 ml of 90 percent acetone-10 percent saturated $MgCO_3$ solution was added to the tube. Usually one sample consisted of scrapings from 4 slides, consequently the total acetone volume equalled 40 ml. The tubes were placed in a sonic bath for at least 20 minutes to aid pigment extraction, then allowed to steep for at least 24 hours in the dark under refrigeration at 4°C, and sonified again for at least 20 minutes. Pigment optical density readings were made with a Perkin-Elmer Model 200 Spectrophotometer at a resolution setting of 1.0 nanometer and path length of 1.0 centimeter.

Biomass determinations were also done according to the A.P.H.A. (1975) with the following variations. Biomass and chlorophyll measurements were made from the same "pooled" slide samples. Inconel alloy metal crucibles were used for the summer 1978 samples, with Vycor 100 ml glass evaporating dishes being employed for both the Fall 1978 and Spring 1979 samples. Prior to placing the samples in the drying oven, the acetone was evaporated under a bank of sun lamps.

Results

Tables 9 through 13 contain chlorophyll a accrual rates, biomass accrual rates, autotrophic index values, chlorophyll a/pheophytin a ratios, and carotene/chlorophyll ratios, respectively.

Interpretation

Chlorophyll a accrual rates in streams of northwest Montana averaged from 0.02 to 2.53 $mg/m^2/day$ (Table 9). Klarich (1976) reported mean accrual values ranging from 0.7 at Laurel to 12.2 at Huntley for a reach of the Yellowstone River he describes as "mesotrophic". Ingman (1978) found accrual rates averaging 3.1 for a moderately enriched section of Prickly Pear Creek below the Helena sewage treatment plant discharge. At the other extreme, Bahls (1978) reported mean chlorophyll a accrual rates of 0.13 and 0.14 $mg/m^2/day$ for two very oligotrophic northwestern Montana streams. From these previously published data an arbitrary chlorophyll a accrual rate of 0.5 $mg/m^2/day$ can be considered transitional between oligotrophic and mesotrophic status. Applying this criterion to the northwest Montana chlorophyll a accrual rates reveals that 12 of the 16 stations would be classified as oligotrophic. The remaining four stations--Bitterroot River, Clark Fork River at Huson, Middle Fork Flathead River, and Whitefish River -- would thus be classified as mesotrophic in terms of chlorophyll a accrual.

Mean biomass accrual rates in streams of the Northwestern Loop ranged from 9 $mg/m^2/day$ in the Flathead River at Kalispell to 217 $mg/m^2/day$ in the Whitefish River (Table 10). Klarich (1976) reported extreme values of 50 and 730 $mg/m^2/day$ in the Yellowstone River above and below Billings, respectively. Ingman (1978) reported a mean biomass accrual rate of 338 $mg/m^2/day$ for Prickly Pear Creek. Bahls (1978) found mean biomass accrual rates of 115 and 102 $mg/m^2/day$ for the two oligotrophic northwest Montana streams he studied. Whittaker (1970) has determined that normal biomass production rates for streams range from 300 to 4100 $mg/m^2/day$. All stations in the Northwest Loop fell below Whittaker's lowest normal value. Fourteen of the sixteen stations were below the biomass accrual rate of 115 $mg/m^2/day$ that Bahls found on an oligotrophic stream in northwest Montana, further substantiating the oligotrophic status assigned to the majority of the Northwest Loop stations. The two exceptions were the Clark Fork River at Huson and the Whitefish River, with biomass accrual rates of 213 and 217 $mg/m^2/day$, respectively.

Mean autotrophic index (AI) values ranged from 121 to 650 among Northwest Loop stations (Table 11). Only five of the sixteen stations fell below the unpolluted AI criterion of 200: Clark Fork River at Huson, Lake Creek, Middle Fork of the Flathead River, Swiftcurrent Creek, and Whitefish River. With the exception of three stations -- the Clearwater River, Fisher River, and Flathead River near Perma -- all remaining stations had mean AI values below 300 and probably can be considered borderline. Caution should be used in judging these AI values because of error inherent in the biomass procedure.

Mean chlorophyll a/pheophytin a ratios ranged from 1.44 to 1.66 at stations of the Northwest Loop with an overall mean value of 1.58. This indicates that the physiological condition of algae colonizing artificial substrates in northwest Montana streams is fair to good.

Mean "yellow/green" or carotene/chlorophyll ratios were within the very narrow range of 2.13 to 2.50 at all stations in the Northwest Loop. This means that algae communities colonizing artificial substrates in northwestern Montana streams are young and exhibit relatively high chlorophyll a concentrations.

Table 9. Chlorophyll a accrual (mg/m²/day)

Station	Summer	Fall	Spring	Mean
Bitterroot River	0.40	1.45	0.21	0.69
Clark Fork River/ Bonner	0.07	0.67	0.31	0.35
Clark Fork River/ Huson	---	2.40	1.22	1.81
Clearwater River	0.08	0.88	0.07	0.34
Fisher River	0.06	0.12	0.28	0.15
Flathead River/ Kalispell	---	0.05	0.51	0.28
Flathead River/Perma	0.02	---	0.01	0.02
Lake Creek	0.22	0.90	0.21	0.44
Little Blackfoot River	0.33	0.09	0.61	0.34
Middle Fork Flathead River	0.75	0.87	0.77	0.80
North Fork Flathead River	0.20	0.10	0.20	0.17
Stillwater River	0.07	0.08	0.25	0.13
Swan River	---	0.09	0.02	0.06
Swiftcurrent Creek	---	---	0.09	0.09
Whitefish River	---	0.33	4.72	2.53
Yaak River	0.10	0.02	0.05	0.06
Mean	0.21	0.58	0.60	0.49

Table 10. Biomass accrual ($mg/m^2/day$)

Station	Summer	Fall	Spring	Mean
Bitterroot River	106	141	81	109
Clark Fork River/ Bonner	28	69	56	51
Clark Fork River/ Huson	---	270	156	213
Clearwater River	33	118	25	59
Fisher River	32	27	47	35
Flathead River/ Kalispell	---	14	69	42
Flathead River/Perma	11	---	7	9
Lake Creek	50	119	46	72
Little Blackfoot River	55	35	110	67
Middle Fork Flathead River	126	99	98	108
North Fork Flathead River	54	27	37	39
Stillwater River	33	15	21	23
Swan River	---	20	6	13
Swiftcurrent Creek	---	---	11	11
Whitefish River	---	57	376	217
Yaak River	19	7	10	12
Mean	50	73	72	66

Table 11. Autotrophic Index

Station	Summer	Fall	Spring	Mean
Bitterroot River	269	98	384	250
Clark Fork River/ Bonner	413	104	182	233
Clark Fork River/ Huson	---	113	128	121
Clearwater River	552	134	361	349
Fisher River	611	223	168	334
Flathead River/ Kalispell	---	271	134	203
Flathead River/Perma	503	---	797	650
Lake Creek	219	120	220	186
Little Blackfoot River	176	381	186	248
Middle Fork Flathead River	210	111	129	150
North Fork Flathead River	272	285	190	249
Stillwater River	463	226	85	258
Swan River	---	246	267	257
Swiftcurrent Creek	---	---	134	134
Whitefish River	---	201	80	141
Yaak River	188	433	200	274
Mean	352	210	228	255

Table 12. Chlorophyll a/Pheophytin a ratio

Station	Summer	Fall	Spring	Mean
Bitterroot River	1.32	1.66	1.61	1.53
Clark Fork River/ Bonner	1.45	1.67	1.71	1.61
Clark Fork River/ Huson	---	1.64	1.67	1.66
Clearwater River	1.32	1.58	1.55	1.48
Fisher River	1.49	1.67	1.67	1.61
Flathead River/ Kalispell	---	1.65	1.56	1.61
Flathead River/Perma	---	---	1.44	1.44
Lake Creek	1.42	1.64	1.67	1.58
Little Blackfoot River	1.46	1.57	1.68	1.57
Middle Fork Flathead River	1.55	1.69	1.65	1.63
North Fork Flathead River	1.66	1.56	1.65	1.62
Stillwater River	1.57	1.67	1.64	1.63
Swan River	---	1.51	1.61	1.56
Swiftcurrent Creek	---	---	1.64	1.64
Whitefish River	---	1.66	1.64	1.65
Yaak River	1.42	1.44	1.59	1.48
Mean	1.47	1.62	1.62	1.58

Table 13. Carotene/Chlorophyll ratio (OD 430/OD 663)

Station	Summer	Fall	Spring	Mean
Bitterroot River	2.26	2.21	2.27	2.25
Clark Fork River/ Bonner	2.33	2.36	2.33	2.34
Clark Fork River/ Huson	---	2.11	2.15	2.13
Clearwater River	2.50	2.11	2.46	2.36
Fisher River	2.36	2.20	2.27	2.28
Flathead River/ Kalispell	---	2.38	2.17	2.28
Flathead River/Perma	2.51	---	2.48	2.50
Lake Creek	2.22	2.07	2.10	2.13
Little Blackfoot River	2.07	2.29	2.08	2.15
Middle Fork Flathead River	2.17	2.14	2.18	2.16
North Fork Flathead River	2.19	2.18	2.21	2.19
Stillwater River	2.32	2.09	2.22	2.21
Swan River	---	2.45	2.39	2.42
Swiftcurrent Creek	---	---	2.15	2.15
Whitefish River	---	2.17	2.23	2.20
Yaak River	2.42	2.36	2.32	2.37
Mean	2.31	2.22	2.25	2.26

PERIPHYTON COMMUNITY STRUCTURE

Rationale

Except in the lower reaches of our largest rivers -- the Kootenai, Clark Fork, Missouri, and Yellowstone -- the stream periphyton (bottom) community is more important than the stream plankton (open water) community in terms of plant diversity and plant production. The periphyton community often has more than 300 different kinds of plants (mostly single-celled algae) on one square inch of river bottom.

In unpolluted waters, the dominant algae are diatoms. Diatoms are microscopic, golden-brown plants encased in silica. They are often attached to the river bottom by a short gelatinous stalk. Millions of these creatures underfoot can make a river bottom treacherous, yet they are a sign of good river health. Moreover, they are the preferred food of many aquatic invertebrates.

When a river is polluted and its chemical and biological equilibrium is disturbed, diatoms are often displaced by coarser, less palatable green and blue-green algae (Patrick, 1978). In Montana streams, this take-over is usually accomplished by the long, filamentous green alga *Cladophora*, which often becomes a nuisance. For this reason we have ranked diatoms relative to other significant algae as a rough index of stream well-being. Theoretically, the lower diatoms are ranked, the more polluted and unbalanced is the river. It should be noted that some non-diatom algae may be seasonally very abundant in nearly pristine streams, for example the blue-green alga *Nostoc*.

Each one of the many thousand different species of stream diatoms is unique in the conditions it requires for growth. Many of the more common species have been classified as to their general environmental requirements and pollution tolerances (Lowe, 1974). They run the gamut from tolerant to intolerant. Consequently, diatoms are valuable pollution indicators and subtle shifts within the diatom association on a river bottom can signal environmental disturbances long before a stream becomes totally "unglued" and nuisance growths appear.

Achnanthes and *Nitzschia* are two particularly useful diatom indicators. *Achnanthes* is almost always found in significant numbers, but only in water having a high concentration of dissolved oxygen, approaching saturation. *Nitzschia*, on the other hand, is usually associated with waters high in nitrogen. The relative abundance of *Nitzschia* is often directly proportional to the amount of nitrogen contained in the water. Some species of *Nitzschia*, such as *N. palea*, require organic nitrogen for their growth (Cholnoky, 1968).

Clean waters usually have many different species with some fairly common but with none really dominant. Polluted waters have fewer species, often with one or two species very abundant. Clean water is said to have high diversity and polluted water is said to have low diversity. Diversity can be measured simply by counting the number of species in a sample or by calculating a rather involved formula called a diversity index. The most widely accepted diversity index is the Shannon-Weaver Index or $\bar{d}$. Bahls (1979) found that benthic diatom associations in unpolluted Montana streams usually had more than 25 species and $\bar{d}$ values greater than 3. Species numbers significantly less than 25 and diversity values significantly below 3 may be indicative of pollution.

Methods

Periphytic algae were collected from natural substrates on the stream bottom. Quantities of larger, macroscopic species were picked in proportion to their abundance relative one to one another and to the attached diatom (slime) community as a whole. Accordingly, an appropriate amount of the diatom community was collected by scraping rocks and other submerged substrates with a razor blade, pocket knife or scalpel. Different substrates in turn were scraped in proportion to their areal coverage. An effort also was made to collect algae from both pools and riffles, again in proportion to the extent these stream features prevail at a given site. The ultimate objective is to obtain a sample of algae that is a miniature replicate of the stream's periphyton community. Samples were preserved with Lugol's (IKI) solution and returned to the lab for analyses.

Conspicuous non-diatom algae were removed, examined microscopically, and identified to genus. The relative abundance and rank of each significant non-diatom genus and the diatom community as a whole were then recorded. A portion of the diatom community was used to prepare a permanent, randomly strewn mount using sulfuric acid and potassium dichromate as the oxidizing agents and Cargille's "Carmount-165" as the mounting medium (A.P.H.A., 1975). A diatom species proportional count was performed on each slide following the technique outlined by Weber (1973), except that in excess of 300 rather than 250 cells were tallied. The results were used to compute percent relative abundance of indicator taxa and diatom species diversity using the Shannon-Weaver formula recommended by Weber (1973):

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \sum n_i \log_{10} n_i)$$

where C = 3.321928; N = total number of individuals; and n_i = number of individuals in the i^{th} species.

Results

Parameters depicting periphyton community structure are presented in Tables 14 through 19. Appendix G lists names and water quality requirements of major diatom species presented in Table 15.

Interpretation

Diatoms dominated the periphyton of most streams in the Northwest Loop (Table 14). Relatively large amounts of the green algae *Spirogyra* and *Stigeoclonium* indicate occasional temperature and nutrient problems in the Clearwater, Fisher, Stillwater, and Yaak rivers. Of the dominant (rank = 1) non-diatom algae in northwest Montana streams, the genus *Spirogyra* occurred most frequently (5 times), followed by *Stigeoclonium* (4), *Phormidium* and

Oedogonium (2), and *Nostoc, Tribonema, Microspora, Hildenbrandtia, Audouinella, Batrachospermum,* and *Ulothrix* (1).

Most of the major diatom species from the Northwest Loop (Table 15 and Appendix G) indicate cool, circumneutral, and moderately enriched water. "Eutrophic" species ranked first among the major diatom species in Swiftcurrent Creek and in the Clark Fork (Bonner), Fisher, Little Blackfoot, Middle Fork Flathead, and Whitefish rivers. However, none of the diatom associations were typical of extremely eutrophic conditions. As it was in the Southwest Loop (Bahls et al., 1979), *Achnanthes minutissima* (ACMI) was the most abundant diatom in northwest Montana streams. This is a cosmopolitan species but it thrives only in streams with a dissolved oxygen content close to saturation (Cholnoky, 1968).

Total relative abundance values for all *Achnanthes* species (oxygen indicators) are listed in Table 16. The Little Blackfoot River had the lowest mean value, followed by the Clark Fork River (both stations) and the Whitefish River. Swiftcurrent Creek also had an extremely low value for the fall 1978 run. Of all the streams in the Northwest Loop, these four are most likely to suffer from depressed dissolved oxygen concentrations.

Total relative abundance values for all *Nitzschia* species (nitrogen indicators) are listed in Table 17. Besides having the lowest mean *Achnanthes* levels, the Clark Fork River (both stations), the Little Blackfoot River, and the Whitefish River also had the highest mean *Nitzschia* levels. The Fisher River and the Stillwater River also had *Nitzschia* levels indicating at least periodic nitrogen enrichment.

Mean numbers of diatom species and mean diatom species diversity ($\bar{d}$) values (Tables 18 and 19) indicate the absence of biologically debilitating pollution at all stations of the Northwest Loop.

Table 14. Estimated rank of diatoms and other significant algae, by volume.

Station	Summer	Fall	Spring
Bitterroot River	1. Diatoms 2. *Phormidium* 3. *Stigeoclonium* 4. *Audouinella*	1. Diatoms 2. *Ulothrix* 3. *Cladophora* 4. *Phormidium* 5. *Scenedesmus* 6. *Ankistrodesmus* 7. *Cosmarium*	1. Diatoms 2. *Phormidium*
Clark Fork River/ Bonner	1. Diatoms 2. *Stigeoclonium* 3. *Cladophora* 4. *Phormidium*	1. Diatoms 2. *Cladophora* 3. *Ulothrix* 4. *Pediastrum*	1. Diatoms 2. *Phormidium* 3. *Hydrurus* 4. *Ulothrix*
Clark Fork River/ Huson	1. Diatoms 2. *Stigeoclonium* 3. *Phormidium*	1. Diatoms 2. *Ulothrix* 3. *Pediastrum* 4. *Oedogonium* 5. *Scenedesmus*	1. Diatoms 2. *Tribonema*
Clearwater River	1. *Spirogyra* 2. *Stigeoclonium* 3. Diatoms 4. *Lemanea* 5. *Anabaena* 6. *Audouinella* 7. *Phormidium*	1. *Spirogyra* 2. Diatoms 3. *Chaetophora* 4. *Anabaena* 5. *Pediastrum* 6. *Stigeoclonium* 7. *Phormidium*	1. Diatoms
Fisher River	1. *Stigeoclonium* 2. Diatoms 3. *Cosmarium*	1. *Spirogyra* 2. Diatoms	1. Diatoms 2. *Hydrurus* 3. *Ulothrix*
Flathead River/ Kalispell	1. Diatoms 2. *Ulothrix*	1. Diatoms 2. *Ulothrix* 3. *Stigeoclonium*	1. Diatoms
Flathead River/ Perma	1. Diatoms 2. *Stigeoclonium* 3. *Tolypothrix*	1. Diatoms 2. *Zygnema* 3. *Spirogyra* 4. *Mougeotia* 5. *Oedogonium* 6. *Anabaena*	1. *Nostoc* 2. Diatoms 3. *Phormidium*

Table 14. (Continued)

Station	Summer	Fall	Spring
Lake Creek	1. *Phormidium* 2. Diatoms 3. *Ulothrix*	1. *Phormidium* 2. Diatoms 3. *Spirogyra* 4. *Ulothrix*	1. Diatoms 2. *Phormidium* 3. *Hydrurus*
Little Blackfoot River	1. *Tribonema* 2. *Vaucheria* 3. *Nostoc* 4. Diatoms 5. *Closterium* 6. *Audouinella* 7. *Stigeoclonium*	1. *Microspora* 2. *Nostoc* 3. Diatoms 4. *Vaucheria* 5. *Ulothrix* 6. *Spirogyra* 7. *Oedogonium* 8. *Closterium* 9. *Zygnema* 10. *Cladophora*	1. Diatoms 2. *Phormidium* 3. *Nostoc* 4. *Ulothrix* 5. *Audouinella*
Middle Fork Flathead River	1. Diatoms 2. *Ulothrix*	1. *Stigeoclonium* 2. Diatoms 3. *Phormidium* 4. *Ulothrix*	1. Diatoms 2. *Hydrurus* 3. *Phormidium*
North Fork Flathead River	1. *Stigeoclonium* 2. Diatoms	1. Diatoms 2. *Nostoc* 3. *Rivularia* 4. *Hildenbrandtia* 5. *Stigeoclonium*	1. *Hildenbrandtia* 2. Diatoms 3. *Stigeoclonium*
Stillwater River	1. *Audouinella* 2. *Spirogyra* 3. *Chaetophora* 4. *Nostoc* 5. Diatoms 6. *Cosmarium* 7. *Phormidium*	1. *Spirogyra* 2. Diatoms 3. *Audouinella* 4. *Nostoc*	1. Diatoms 2. *Audouinella* 3. *Rhizoclonium*
Swan River	1. Diatoms 2. *Schizoclamys* 3. *Chara* 4. *Rivularia* 5. *Phormidium* 6. *Stigeoclonium*	1. *Batrachospermum* 2. Diatoms 3. *Stigeoclonium* 4. *Bulbochaete* 5. *Oedogonium* 6. *Zygnema* 7. *Mougeotia*	1. Diatoms 2. *Rivularia* 3. *Microspora*
Swiftcurrent Creek	1. *Ulothrix* 2. Diatoms	1. Diatoms 2. *Ulothrix* 3. *Stigeoclonium*	1. Diatoms

Table 14. (Continued)

Station	Summer	Fall	Spring
Whitefish River	1. *Oedogonium* 2. *Hildenbrandtia* 3. *Stigeoclonium* 4. Diatoms 5. *Phormidium*	1. *Oedogonium* 2. *Chlorella* 3. Diatoms 4. *Nostoc* 5. *Spirogyra* 6. *Rhizoclonium*	1. Diatoms 2. *Amphithrix* 3. *Chlorella* 4. *Hormidium* 5. *Nostoc*
Yaak River	1. *Spirogyra* 2. *Stigeoclonium* 3. Diatoms 4. *Tolypothrix* 5. *Audouinella*	1. *Stigeoclonium* 2. *Oedogonium* 3. *Spirogyra* 4. *Phormidium* 5. Diatoms 6. *Mougeotia* 7. *Ulothrix* 8. *Tolypothrix*	1. Diatoms 2. *Tolypothrix* 3. *Phormidium* 4. *Chaetophora* 5. *Calothrix* 6. *Ulothrix*

Table 15. Percent relative abundance of major diatom species (Appendix G)

Station	Summer	Fall	Spring
Bitterroot River	ACMI: 42.3	ACMI: 10.2	ACMI: 50.6
Clark Fork River/Bonner	NIFR: 16.7 ACMI: 14.5	ACMI: 10.2	FRVA: 29.5 GOOL: 19.2
Clark Fork River/Huson	CMAF: 15.3 NIFR: 10.3	CMAF: 23.7	CMMN: 11.8 NIRO: 10.9
Clearwater River	ACMI: 15.5	ACMI: 17.8 CMCM: 14.7 CMMC: 14.7	ACDE: 23.6 FRVA: 21.0
Fisher River	EPSO: 30.8 ACMI: 25.9	COPL: 12.8 APPE: 12.3 ACMI: 11.2 EPSO: 11.2 CMMC: 10.4	ACMI: 40.6 GOOV: 20.2
Flathead River/Kalispell	ACMI: 31.8 SYUL: 10.9	ACMI: 44.7	ACMI: 44.7 FRVA: 12.2
Flathead River/Perma	CMMC: 22.9 ACDE: 19.0 ACMI: 18.3	CMMC: 10.7	ACMI: 18.8
Lake Creek	ACMI: 37.1 HAAR: 19.1	ACMI: 41.5	ACMI: 41.7 ACDE: 10.7
Little Blackfoot River		FRVA: 10.6	NIDI: 21.1 FRVA: 18.1
Middle Fork Flathead River	ACMI: 40.9 ACL I: 13.4 SYUL: 12.1	SYUL: 34.2 CMAF: 23.9 ACMI: 12.5	DIHI: 19.0 ACMI: 18.0 ACDE: 10.0
North Fork Flathead River	ACMI: 55.4 ACL I: 13.3	ACMI: 32.8 SYUL: 15.5	ACMI: 45.6
Stillwater River	ACMI: 30.2 NIDI: 11.0 FRVA: 10.8	ACMI: 31.9 FRVA: 10.6	ACMI: 32.2 FRVA: 15.3 SYMI: 11.7
Swan River	ACMC: 18.7 ACMI: 13.4	ACMC: 32.3 CMMC: 10.4	ACMC: 28.1 CMMC: 14.0 ACDE: 11.0

Table 15. (Continued)

Station	Summer	Fall	Spring
Swiftcurrent Creek	SYUL: 27.5 ACMI: 17.9 FRVA: 14.9	SYUL: 47.0 FRVA: 13.1	ACMI: 39.1 FRVA: 13.2
Whitefish River	ACMI: 18.8 COPL: 16.1 GOOV: 12.9	FRVA: 32.7 ACMI: 16.1	GOOL: 13.8 EPSO: 11.3
Yaak River	ACMI: 60.6	ACMI: 38.0	ACMI: 59.8 CMMC: 10.1

Table 16. Percent relative abundance of Achnanthes species

Station	Summer	Fall	Spring	Mean
Bitterroot River	47.0	50.3	57.9	51.7
Clark Fork River/Bonner	16.1	11.4	5.3	10.9
Clark Fork River/Huson	14.5	6.7	8.8	10.0
Clearwater River	22.7	28.5	31.1	27.4
Fisher River	27.3	13.6	41.4	27.4
Flathead River/Kalispell	52.3	56.1	52.1	53.5
Flathead River/Perma	39.2	16.9	27.3	27.8
Lake Creek	44.2	51.1	56.4	50.6
Little Blackfoot River	10.2	6.9	8.3	8.5
Middle Fork Flathead River	61.3	25.5	44.0	43.6
North Fork Flathead River	78.2	38.1	56.0	57.4
Stillwater River	33.2	33.8	33.6	33.5
Swan River	38.1	39.0	49.3	42.1
Swiftcurrent Creek	24.3	2.8	45.2	24.1
Whitefish River	20.7	18.2	8.7	15.9
Yaak River	64.3	43.9	62.2	56.8
Mean	37.1	27.7	36.7	33.8

Table 17. Percent relative abundance of Nitzschia species

Station	Summer	Fall	Spring	Mean
Bitterroot River	10.1	9.2	8.2	9.2
Clark Fork River/Bonner	28.9	20.9	5.1	18.3
Clark Fork River/Huson	25.8	21.4	27.2	24.8
Clearwater River	3.0	2.4	6.8	4.1
Fisher River	9.6	11.1	15.9	12.2
Flathead River/Kalispell	0.8	5.0	1.4	2.4
Flathead River/Perma	2.9	7.1	7.5	5.8
Lake Creek	1.4	2.0	2.7	2.0
Little Blackfoot River	16.6	9.7	35.3	20.5
Middle Fork Flathead River	1.9	0.8	4.9	2.5
North Fork Flathead River	1.1	4.0	3.4	2.8
Stillwater River	14.2	8.6	2.9	8.6
Swan River	3.6	2.2	3.6	3.1
Swiftcurrent Creek	1.4	2.3	2.4	2.0
Whitefish River	18.8	8.5	12.4	13.2
Yaak River	2.1	2.6	2.6	2.4
Mean	8.9	7.4	8.9	8.4

Table 18. Number of diatom species

Station	Summer	Fall	Spring	Mean
Bitterroot River	57	75	76	69
Clark Fork River/Bonner	70	78	70	73
Clark Fork River/Huson	66	89	84	80
Clearwater River	99	81	88	89
Fisher River	62	61	50	58
Flathead River/Kalispell	48	76	60	61
Flathead River/Perma	61	93	109	88
Lake Creek	63	83	70	72
Little Blackfoot River	76	77	80	78
Middle Fork Flathead River	50	48	67	55
North Fork Flathead River	35	72	68	58
Stillwater River	59	73	65	66
Swan River	73	108	94	92
Swiftcurrent Creek	43	46	53	47
Whitefish River	49	74	67	63
Yaak River	57	78	65	67
Mean	60	76	73	70

Table 19. Diatom species diversity ($\bar{d}$).

Station	Summer	Fall	Spring	Mean
Bitterroot River	3.68	3.59	3.32	3.53
Clark Fork River/Bonner	4.54	5.07	3.90	4.50
Clark Fork River/Huson	4.66	4.70	4.59	4.65
Clearwater River	4.94	4.13	3.85	4.31
Fisher River	3.70	4.40	3.16	3.75
Flathead River/Kalispell	3.68	3.55	3.31	3.51
Flathead River/Perma	3.92	5.31	5.03	4.75
Lake Creek	3.30	3.76	3.81	3.62
Little Blackfoot River	5.07	4.80	4.32	4.73
Middle Fork Flathead River	3.26	3.01	4.13	3.47
North Fork Flathead River	2.52	3.95	3.40	3.29
Stillwater River	3.85	4.05	3.56	3.82
Swan River	4.32	4.16	4.16	4.21
Swiftcurrent Creek	3.54	3.06	3.32	3.31
Whitefish River	4.05	3.97	4.63	4.22
Yaak River	2.85	4.10	2.55	3.17
Mean	3.86	4.10	3.82	3.93

MACROINVERTEBRATE COMMUNITY STRUCTURE

Rationale

Macroinvertebrates comprise the energy link between periphyton and fish. They include detritus feeders, parasites, scavengers, grazers, and predators. Most organisms in this community of bottom dwellers are immature insect forms. As with the periphyton, benthic macroinvertebrates are differentially tolerant to pollution. Because of their limited mobility and relatively long life span (up to three years in some species) the invertebrates, like some periphyton, reflect the water quality conditions of the recent past. They integrate or are a function of the water quality constituents over a period of time.

Of the common aquatic insects in Montana streams, three groups (orders) are generally used as indicators of waters with little organic pollution or oxygen-demanding wastes. These are the stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). These three groups and two others -- the true flies (Diptera) and beetles (Coleoptera) -- each contain species that prefer, are indifferent to, or are completely intolerant of pollution. The remaining common group of aquatic insects, the true bugs (Hemiptera), is generally considered tolerant of organic pollution. Although water quality preferences for many stream insects are not known, the relative abundance of organisms in these various groups gives a good approximation of water quality conditions.

In the typical unstressed situation, there should be a large number of taxa with few individuals in each one. This instance gives a high diversity value, emphasizing good quality water and habitat availability. Stressed waters generally have few taxa with one or two dominant. The number of macroinvertebrate taxa and macroinvertebrate diversity are considered good estimators of community health. Wilhm (1970) reported clean waters to have from 11 to 54 species and Shannon-Weaver diversity values from 2.6 to over 4. On the other hand, polluted streams had diversity values less than 2 and frequently less than 1. From our experience, unpolluted streams with favorable substrate, oxygen levels, and temperature generally produce a minimum of 15 genera and often between 20 and 30 genera and higher depending on stream order and season of collection. Diversities computed from samples of less than 100 organisms should be interpreted with caution (Weber, 1973), as such samples may not be statistically reliable.

The number of individual organisms collected may also indicate relative productivity and/or habitat availability, assuming about the same amount of effort went into each collection.

Methods

The technique used for macroinvertebrate collection is a modification of the "unit effort traveling kick" method described by Kinney _et al_. (1978). The objective is to sample each type of habitat at the designated site and to apply a similar amount of effort at each station. Where macroinvertebrates are scarce, additional effort may be required in order to collect a statistically significant number of specimens. Equipped with a long-handled D-frame aquatic net (Ward's 10W0620)*, the sampler works all the major habitat types -- riffles, pools, submerged vegetation, etc. -- by dislodging organisms with his feet and capturing them as they drift downstream. Research has shown this method to have better statistical reproducibility than artificial substrate and Surber samplers in semi-arid regions where the fauna tends to be patchy and sparse (Hornig and Pollard, 1978).

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*Approximately 21.5 meshes per inch with 1 mm openings

When an adequate number of insects has been collected, the sampler randomly selects 100 or more specimens from the net and places them in a small jar filled one-third full of water. (At some sites 100 organisms cannot be collected in a reasonable length of time, even with additional effort.) Care is taken not to be biased by size of the organism. The jar is then filled with 95 percent ethanol, labeled, and returned to the laboratory for analysis. A few drops of glycerine are added if extended storage is required.

Organisms were identified to genus wherever possible. Enumeration results were used to compute the percent relative abundance of individuals in major pollution sensitivity groups (orders). Shannon-Weaver diversity was calculated in the same fashion as it was for the diatoms (See "PERIPHYTON COMMUNITY STRUCTURE -- Methods ").

Results

Macroinvertebrate community parameters are presented in Tables 20 through 23. The main problem encountered in macroinvertebrate sampling on the Northwest Loop was capturing a statistically reliable number of insects in a reasonable time. This may be partly due to the oligotrophic waters in this part of the state. Approximately half of the total number of insect samples had less than the prescribed 100 individuals needed for good statistical evaluations. At four stations, less than 100 insects were collected on all three collecting trips. In all cases the lack of suitable substrate, or difficulty in sampling it, was the cause of not obtaining the desired 100 individuals.

Interpretation

At all stations, with the exception of the Flathead River at its mouth, at least 70% of the organisms collected were stoneflies, mayflies, and caddisflies: those groups generally accepted as indicating little organic pollution.

Numbers of macroinvertebrate genera varied somewhat from stream to stream and from season to season. This was partially due to sampling conditions, but also was due to increased taxonomic proficiency as sampling progressed. For this reason it is believed that more emphasis should be placed on the spring data, which were collected last.

The spring samples are statistically reliable with the exception of the two Clark Fork River samples and the two mainstem Flathead River samples, which had less than the desired 100 individuals. It is believed that the use of different sampling techniques at these four stations would produce more invertebrate numbers and genera and thus more reliable diversity values. Nevertheless, the mean number of genera and mean diversity values at these four stations ranged from 9 to 16 and from 2.27 to 3.37, respectively, indicating fair to good conditions. The number of genera at the other stations for the spring sampling ranged from 15 to 32, with diversity values ranging from 2.76 to 4.37. These numbers reflect the good to excellent water quality conditions at most stations in the Northwest Loop.

Table 20. Mean percent relative abundance of insects in the major macroinvertebrate orders

Station	Plecoptera (stoneflies)	Ephemeroptera (mayflies)	Trichoptera (caddisflies)	Diptera (true flies)	Coleoptera (beetles)	Hemiptera (true bugs)	Miscellaneous
Bitterroot River	13	31	37	14	<5	<5	<5
Clark Fork River/ Bonner	34	23	37	<5	<5	0	<5
Clark Fork River/ Huson	35	35	12	16	<5	0	<5
Clearwater River	20	13	51	12	<5	<5	<5
Fisher River	21	27	29	22	<5	0	<5
Flathead River/ Kalispell	25	51	8	12	<5	0	<5
Flathead River/ Perma	5	32	11	50	<5	<5	<5
Lake Creek	19	29	22	29	<5	<5	<5
Little Blackfoot River	22	39	12	24	<5	0	<5
Middle Fork Flathead River	27	32	21	14	<5	0	<5
North Fork Flathead River	25	44	16	12	<5	0	<5
Stillwater River	36	16	21	19	<5	0	<5
Swan River	18	10	56	8	<5	0	<5
Swiftcurrent Creek	31	16	36	17	0	0	0
Whitefish River	6	37	36	9	5	<5	<5
Yaak River	22	28	31	8	7	0	<5
Mean	22	29	27	17	<5	<5	<5

Table 21. Number of macroinvertebrate genera collected

Station	Summer	Fall	Spring	Mean
Bitterroot River	19	16	17	17
Clark Fork River/ Bonner	14	14	10	13
Clark Fork River/ Huson	16	14	18	16
Clearwater River	14	16	29	20
Fisher River	18	18	15	17
Flathead River/ Kalispell	14	13	8	12
Flathead River/Perma	10	2	15	9
Lake Creek	19	16	28	21
Little Blackfoot River	15	18	22	18
Middle Fork Flathead River	17	17	32	22
North Fork Flathead River	17	16	22	18
Stillwater River	11	13	27	17
Swan River	9	12	21	14
Swiftcurrent Creek	9	6	16	10
Whitefish River	15	23	27	22
Yaak River	15	12	19	15
Mean	15	14	20	16

Table 22. Macroinvertebrate genus diversity

Station	Summer	Fall	Spring	Mean
Bitterroot River	3.46	3.16	3.20	3.27
Clark Fork River/ Bonner	3.03	2.34	2.43	2.60
Clark Fork River/ Huson	3.24	3.42	3.46	3.37
Clearwater River	3.01	2.63	4.14	3.26
Fisher River	2.83	3.27	3.40	3.17
Flathead River/ Kalispell	2.56	3.05	1.93	2.51
Flathead River/Perma	2.95	0.72	3.15	2.27
Lake Creek	2.52	3.57	4.11	3.40
Little Blackfoot River	3.48	3.47	2.76	3.24
Middle Fork Flathead River	3.25	3.18	4.37	3.60
North Fork Flathead River	3.51	3.16	3.57	3.41
Stillwater River	3.19	2.69	3.94	3.27
Swan River	2.40	2.46	3.54	2.80
Swiftcurrent Creek	2.08	1.17	3.08	2.11
Whitefish River	2.74	3.62	3.81	3.39
Yaak River	3.29	2.93	3.71	3.31
Mean	2.97	2.80	3.41	3.06

Table 23. Number of macroinvertebrate organisms collected

Station	Summer	Fall	Spring	Mean
Bitterroot River	108	113	168	130
Clark Fork River/ Bonner	79	91	79	83
Clark Fork River/ Huson	93	98	83	91
Clearwater River	94	103	159	119
Fisher River	138	133	125	132
Flathead River/ Kalispell	40	32	33	35
Flathead River/Perma	25	5	55	28
Lake Creek	206	50	162	139
Little Blackfoot River	102	95	180	126
Middle Fork Flathead River	60	105	123	96
North Fork Flathead River	43	90	148	94
Stillwater River	26	107	144	92
Swan River	36	146	156	113
Swiftcurrent Creek	99	101	113	104
Whitefish River	102	131	135	123
Yaak River	76	42	119	79
Mean	83	90	124	99

SUMMARY AND CONCLUSIONS

This report presents data for 30 biologically-related water quality parameters at 16 stations over three seasons. There is clearly a need for consolidating this information so that stations in the Northwest Loop can be compared at a glance and prioritized from the standpoint of management requirements.

One such consolidation scheme incorporates mean values for the following key indicators:

1. Specific conductance (micromhos @ 25 C) (summer only)
2. Total soluble inorganic nitrogen (mg/l)
3. Total phosphorus (mg/l)
4. Algal assay control mean maximum standing crop (mg/l) (summer only)
5. Chlorophyll a accrual (mg/m^2/day)
6. Biomass accrual (mg/m^2/day)
7. Autotrophic Index (Biomass accrual/Chlorophyll a accrual)
8. Chlorophyll a/Pheophytin a ratio
9. Carotene/Chlorophyll ratio
10. Percent relative abundance *Achnanthes* species
11. Percent relative abundance *Nitzschia* species
12. Number of diatom species
13. Diatom species diversity ($\bar{d}$)
14. Number of macroinvertebrate genera
15. Macroinvertebrate genus diversity ($\bar{d}$)
16. Number of macroinvertebrate organisms collected

In this scheme, the assumption is made that the least amount of nutrients and production, whatever the cause, is the most desirable case. All mean values are listed in order from lowest to highest for each indicator. Indicators where the highest value is presumed to reflect the best water quality are numbers 8, 9, 10 and 12 - 16 in the list above. Indicators where the lowest value is presumed to reflect the best water quality are numbers 1-7 and 11. The station with the extreme (highest or lowest) value indicating the poorest water quality is given a ranking of one for that indicator. The station with the second highest or lowest value indicating the second poorest water quality is then given a rank of two, and so on until all 16 stations have been ranked for that indicator. When all 16 stations have been ranked for each of the 16 indicators, ranks for each station are totaled and divided by the number of indicators measured at that station. The resulting composite rank may be used to assess relative biological health among the 16 stations of the Northwest Loop. Composite rankings, arranged in order from the highest (best quality) to the lowest (worst quality), are presented in Table 24.

The core of the biological monitoring program is the algae and macroinvertebrate collections. Indicators derived from these collections reflect water quality over an extended period of time. Other parameters reflect water quality only at the time of sampling or at most over the relatively short period during which chlorophyll and biomass are allowed to accumulate on the Periphytometers. The most accepted and useful expression of water quality based on these biological collections is the diversity index, usually the Shannon-Weaver Index (Weber, 1973). Diatom and macroinvertebrate diversity

Table 24. Composite ranking of stations in the Northwest Loop. Best possible rank = 16; worst possible rank = 1.

Station	Rank
Swan River	10.3
Yaak River	10.1
Lake Creek	10.0
Clearwater River	9.5
North Fork Flathead River	9.2
Middle Fork Flathead River	9.2
Swiftcurrent Creek	8.6
Fisher River	8.4
Flathead River/Kalispell	8.1
Flathead River/Perma	7.9
Bitterroot River	7.9
Stillwater River	7.8
Whitefish River	7.6
Clark Fork River/Bonner	6.9
Little Blackfoot River	6.5
Clark Fork River/Huson	6.2

index values have been computed for samples collected over a broad range of water quality conditions (Wilhm, 1970; Bahls, 1979). Generally water quality may be related to Shannon-Weaver diversity values in the following manner:

Water Quality	Diatom Diversity	Macroinvertebrate Diversity	Overall Diversity
Excellent	> 4.50	> 3.50	> 4.00
Good	3.50-4.50	2.50-3.50	3.00-4.00
Fair	2.50-3.50	1.50-2.50	2.00-3.00
Poor	< 2.50	< 1.50	< 2.00

In our experience, diatom diversities usually run somewhat higher than macroinvertebrate diversities. This is probably because it is more difficult to collect representative macroinvertebrate samples, particularly in large rivers, and because insects are rarely identified to species whereas diatoms are always enumerated at the species level and often at the varietal level. It should be kept in mind that these diversity values reflect only the water quality conditions required to sustain these two biological communities; they may not reflect specific water quality requirements of fish and most definitely do not reflect habitat requirements of fish. However, without sufficient water quality to protect the algae and macroinvertebrate populations upon which fish depend for survival, there would be no fishery.

Overall mean biological diversity values and the general water quality conditions they reflect are presented in Table 25. Although subtle differences in water quality are expressed by the rankings in Table 24, the entire span from best to worst is scarcely four points. Diversity values in Table 25 suggest that these differences are not significant from the standpoint of the capacity of these waters to support healthy and stable benthic communities; all stations but one had diversity values reflecting "good" to "excellent" water quality. Consequently, it may be concluded that most of the stations of the Northwest Loop were without serious, biologically-debilitating water quality problems over the course of this survey.

The one exception to this generally healthy picture is Swiftcurrent Creek, which rated "fair" overall. There are no permitted discharges to Swiftcurrent Creek above our sampling site (Botz and Garvin, 1977). Consequently, the problem at this location, if it is man-caused, probably stems from non-point source pollution. Further investigation is advised.

Conditions at these 16 stations cannot be considered totally representative of overall water quality in northwestern Montana. First, one or two stations on a long river are almost never representative of that stream's water quality over its entire length. Second, the parameters measured may not reflect the effects of certain forms of pollution, namely the chronic and bioaccumulative effects of toxins, bacterial contamination, or high temperature, dissolved gas, and dewatering problems. Third, station selection resulted in a bias toward larger streams traversing the more populated valleys.

Table 25. Water quality based on the mean of seasonal biological diversities

Station	Mean Diatom Diversity	Mean Macroinvertebrate Diversity	Overall Mean Diversity	Water Quality
Bitterroot River	3.53	3.27	3.40	Good
Clark Fork River/ Bonner	4.50	2.60	3.55	Good
Clark Fork River/ Huson	4.65	3.37	4.01	Excellent
ClearwaterRiver	4.31	3.26	3.78	Good
Fisher River	3.75	3.17	3.46	Good
Flathead River/ Kalispell	3.51	2.51	3.01	Good
Flathead River/Perma	4.75	2.27	3.51	Good
Lake Creek	3.62	3.40	3.51	Good
Little Blackfoot River	4.73	3.24	3.98	Good
Middle Fork Flathead River	3.47	3.60	3.54	Good
North Fork Flathead River	3.29	3.41	3.35	Good
Stillwater River	3.82	3.27	3.54	Good
Swan River	4.21	2.80	3.50	Good
Swiftcurrent Creek	3.31	2.11	2.71	Fair
Whitefish River	4.22	3.39	3.80	Good
Yaak River	3.17	3.31	3.24	Good
Mean	3.93	3.06	3.49	Good

Consequently, the locally severe effects of mining, agricultural, and forestry non-point pollution in many of the smaller tributary streams will not be represented in this survey (Schmidt and Botz, 1978; Hehn, 1978; Rasmussen and Culwell, 1978). However, most small tributary streams in northwest Montana, particularly those originating in mountainous areas, probably have water quality equal or superior to the quality of waters surveyed in the Northwest Loop.

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APPENDIXES

Appendix A. Streams and stations in the Montana biological monitoring network

SOUTHWEST LOOP (Report completed in February 1979)

Beaverhead River at Twin Bridges
Big Hole River near Twin Bridges
Boulder River below Boulder
Clark Fork River at Deer Lodge
East Gallatin River near Belgrade
Grasshopper Creek near mouth near Dillon
Jefferson River near Three Forks
Madison River near Three Forks
Muddy Creek at mouth near Dell
Prickly Pear Creek at East Helena
Prickly Pear Creek near mouth
Red Rock River above Lima Reservoir
Ruby River near Twin Bridges
Sheep Creek above Muddy Creek
Silver Bow Creek below Warm Springs Ponds
West Fork Madison River near mouth
West Gallatin River at Central Park (I90)

NORTHCENTRAL LOOP (Report completed in March 1979)

Big Sandy Creek near mouth
Dearborn River near mouth
Lodge Creek near Chinook
Marias River near Shelby
Marias River at Loma
Milk River at Havre
Milk River above Chinook
Missouri River at Cascade
Missouri River at Fort Benton
Muddy Creek near mouth at Vaughn
Pondera Creek near mouth near Chester
Smith River near Ulm
Sun River near Fort Shaw
Sun River below Vaughn
Teton River near Dutton
Teton River near Fort Benton

NORTHWEST LOOP (Report completed in November 1979)

Bitterroot River near mouth
Clark Fork River below Bonner Dam
Clark Fork River at Huson RR Bridge
Clearwater River near mouth
Fisher River at mouth
Flathead River near Kalispell
Flathead River near mouth

Appendix A. (Continued)

Northwest Loop (Continued)

- Lake Creek near mouth near Troy
- Little Blackfoot River at Avon
- Middle Fork Flathead River near mouth
- North Fork Flathead River near mouth
- Stillwater River near mouth at Kalispell
- Swan River near mouth
- Swiftcurrent Creek near Babb
- Whitefish River near mouth near Kalispell
- Yaak River near mouth

NORTHEAST LOOP (Report to be completed in 1980)

- Beaver Creek near Hinsdale at Beaverton
- Box Elder Creek near Winnett
- Big Muddy Creek near mouth near Culbertson
- Big Spring Creek below Lewistown
- Judith River near Utica
- Judith River near Danvers
- Judith River near mouth
- Milk River at Nashua
- Missouri River below Judith River
- Missouri River at Fred Robinson Bridge
- Missouri River at Culbertson
- Musselshell River at Harlowton
- Musselshell River above Roundup at Bundy
- Musselshell River below Roundup at Delphia
- Musselshell River at Mosby
- Poplar River at mouth at Poplar
- Redwater River at Circle
- Redwater River near mouth
- Wolf Creek at Stanford
- Wolf Creek at Denton

SOUTHEAST LOOP (Report to be completed in 1980)

- Armell's Creek (East Fork) near Colstrip
- Beaver Creek at Wibaux
- Bighorn River at Bighorn
- Clark's Fork River near Laurel at Edgar
- Little Missouri River at Capitol
- Powder River at Broadus
- Powder River near Miles City at Locate
- Rosebud Creek near Colstrip
- Shields River near mouth
- Tongue River at Brandenberg
- Tongue River at Miles City
- Yellowstone River near Livingston
- Yellowstone River at Billings (USGS Station)
- Yellowstone River near Huntley
- Yellowstone River at Forsyth
- Yellowstone River near Sidney

Appendix B. Phosphate (PO_4 as P in mg/l)

Station	Summer	Fall	Spring	Mean*
Bitterroot River	0.010	0.005	0.016	0.010
Clark Fork River/ Bonner	0.011	0.004	0.040	0.018
Clark Fork River/ Huson	0.016	0.013	0.041	0.023
Clearwater River	0.005	0.002	<0.001	0.002
Fisher River	0.005	<0.001	0.023	0.009
Flathead River/ Kalispell	0.004	0.001	<0.001	0.002
Flathead River/Perma	0.005	0.001	0.016	0.010
Lake Creek	0.005	0.001	<0.001	0.002
Little Blackfoot River	0.024	0.014	0.029	0.022
Middle Fork Flathead River	0.004	<0.001	<0.001	0.001
North Fork Flathead River	0.004	<0.001	<0.001	0.001
Stillwater River	0.005	0.001	0.069	0.025
Swan River	0.004	<0.001	<0.001	0.001
Swiftcurrent Creek	0.005	0.002	<0.001	0.002
Whitefish River	0.014	0.017	0.086	0.039
Yaak River	0.004	<0.001	<0.001	0.001
Mean *	0.008	0.004	0.020	0.011

* Assumes concentrations less than 0.001 mg/l equal zero

Appendix C. Total phosphorus (P in mg/l)

Station	Summer	Fall	Spring	Mean*
Bitterroot River	0.03	0.04	0.02	0.03
Clark Fork River/ Bonner	0.04	0.04	0.05	0.04
Clark Fork River/ Huson	0.04	0.05	0.06	0.05
Clearwater River	0.03	0.02	0.01	0.02
Fisher River	0.02	< 0.01	0.03	0.02
Flathead River/ Kalispell	0.01	0.01	< 0.01	0.01
Flathead River/Perma	0.02	0.01	0.04	0.02
Lake Creek	0.01	0.05	0.01	0.02
Little Blackfoot River	0.03	0.03	0.04	0.03
Middle Fork Flathead River	0.01	< 0.01	< 0.01	0.01
North Fork Flathead River	0.02	0.04	< 0.01	0.02
Stillwater River	0.02	0.01	0.09	0.04
Swan River	0.01	0.01	< 0.01	0.01
Swiftcurrent Creek	0.03	< 0.01	< 0.01	0.01
Whitefish River	0.03	0.03	0.11	0.06
Yaak River	0.01	< 0.01	< 0.01	0.01
Mean*	0.02	0.02	0.03	0.02

* Assumes concentrations less than 0.01 mg/l equal zero

Appendix D. Nitrite plus nitrate ($NO_2 + NO_3$ as N in mg/l).

Station	Summer	Fall	Spring	Mean*
Bitterroot River	0.04	0.04	0.10	0.06
Clark Fork River/ Bonner	<0.01	<0.01	0.12	0.04
Clark Fork River/ Huson	0.02	0.03	0.18	0.08
Clearwater River	<0.01	0.02	0.02	0.01
Fisher River	<0.01	<0.01	0.06	0.02
Flathead River/ Kalispell	0.04	<0.01	0.02	0.02
Flathead River/Perma	0.02	<0.01	0.03	0.02
Lake Creek	0.04	0.02	0.05	0.04
Little Blackfoot River	<0.01	1.10	0.03	0.38
Middle Fork Flathead River	0.12	0.09	0.14	0.12
North Fork Flathead River	<0.01	<0.01	0.02	0.01
Stillwater River	<0.01	<0.01	0.10	0.03
Swan River	<0.01	<0.01	0.03	0.01
Swiftcurrent Creek	0.08	0.01	0.08	0.06
Whitefish River	<0.01	<0.01	0.29	0.10
Yaak River	<0.01	<0.01	0.02	0.01
Mean*	0.02	0.08	0.08	0.06

* Assumes concentrations less than 0.01 mg/l equal zero

Appendix E. Ammonia (NH_3 as N in mg/l)

Station	Summer	Fall	Spring	Mean*
Bitterroot River	0.01	0.03	<0.01	0.01
Clark Fork River/ Bonner	0.02	0.03	0.01	0.02
Clark Fork River/ Huson	0.01	0.02	0.02	0.02
Clearwater River	0.01	0.03	<0.01	0.01
Fisher River	0.01	0.02	<0.01	0.01
Flathead River/ Kalispell	0.01	0.01	<0.01	0.01
Flathead River/Perma	0.01	0.02	<0.01	0.01
Lake Creek	<0.01	0.02	<0.01	0.01
Little Blackfoot River	0.01	0.03	0.01	0.02
Middle Fork Flathead River	0.02	<0.01	<0.01	0.01
North Fork Flathead River	<0.01	0.01	<0.01	<0.01
Stillwater River	0.01	0.01	0.05	0.02
Swan River	<0.01	0.01	<0.01	<0.01
Swiftcurrent Creek	0.01	0.01	<0.01	0.01
Whitefish River	0.01	0.01	0.08	0.03
Yaak River	<0.01	0.02	<0.01	0.01
Mean*	0.01	0.02	0.01	0.01

* Assumes concentrations less than 0.01 mg/l equal zero

Appendix F. Kjeldahl nitrogen (N in mg/l)

Station	Summer**	Fall	Spring	Mean*
Bitterroot River		0.28	0.12	0.20
Clark Fork River/ Bonner		0.18	0.42	0.30
Clark Fork River/ Huson		0.52	0.23	0.38
Clearwater River		0.33	0.08	0.21
Fisher River		0.16	0.17	0.17
Flathead River/ Kalispell		0.22	0.08	0.15
Flathead River/Perma		0.21	0.27	0.24
Lake Creek		0.16	0.37	0.27
Little Blackfoot River		0.28	0.18	0.23
Middle Fork Flathead River		0.24	0.09	0.17
North Fork Flathead River		0.20	0.06	0.13
Stillwater River		0.33	0.30	0.32
Swan River		0.25	<0.05	0.13
Swiftcurrent Creek		0.30	0.12	0.21
Whitefish River		0.19	0.42	0.31
Yaak River		0.18	0.05	0.12
Mean*		0.25	0.19	0.22

*Assumes concentrations less than 0.05 mg/l equal zero
**Samples collected but not analyzed because of equipment failure

Appendix G. Water quality requirements of major diatom species

CODE	SPECIES	WATER QUALITY REQUIREMENTS	REFERENCE(S)
ACDE	*Achnanthes deflexa* Reim.	"Found in moderately hard waters of lakes, streams, and springs (alkaliphil?)"	Patrick and Reimer, 1966
ACLI	*Achnanthes linearis* (W. Sm.) Grun.	Optimum pH 6.5 - 6.8; 0 - 15°C; "high oxygen concentrations"	Lowe, 1974
ACMI	*Achnanthes minutissima* Kutz.	Optimum pH 7.5 - 7.8; "high oxygen concentrations"	Lowe, 1974
ACMC	*Achnanthes microcephala* (Kutz.) Grun.	Optimum pH 6.4 - 6.6; tolerates some salt	Lowe, 1974
APPE	*Amphipleura pellucida* Kutz.	Optimum pH 7.3; eutrophic; hard to slightly brackish water	Lowe, 1974; Patrick and Reimer, 1966
CMAF	*Cymbella affinis* Kutz.	Optimum pH 7.8 - 8.5; summer form; tolerates some salt	Lowe, 1974
CMCM	*Cymbella cymbiformis* Ag.	"Insufficiently known"	Patrick and Reimer, 1975
CMMC	*Cymbella microcephala* Grun.	Optimum pH 7.2; well aerated habitats; tolerates some salt	Lowe, 1974; Patrick and Reimer, 1975
CMMN	*Cymbella minuta* Hilse ex Rabh.	Optimum pH 7.7 - 7.8; widespread; tolerates some salt	Lowe, 1974; Patrick and Reimer, 1975
COPL	*Cocconeis placentula* Ehr.	Optimum pH 8; epiphytic; tolerates some salt	Lowe, 1974
DIHI	*Diatoma hiemale* (Roth) Heib.	Optimum pH 7, range 6.3 - 8.2; cold water; does not tolerate small amounts of salt	Lowe, 1974

Appendix G. Water quality requirements of major diatom species (Continued)

CODE	SPECIES	WATER QUALITY REQUIREMENTS	REFERENCE(S)
EPSO	*Epithemia sorex* Kutz.	Optimum pH 8.3-8.5; eutrophic; tolerates some salt	Lowe, 1974
FRVA	*Fragilaria vaucheriae* (Kutz.) Peters	Optimum pH 6.5-6.9; eutrophic; 0 - 15°C	Lowe, 1974
GOOL	*Gomphonema olivaceum* (Lyngb.) Kutz.	pH range 6.4-9.0; eutrophic; winter or spring form	Lowe, 1974
GOOV	*Gomphonema olivaceoides* Hust.	"Seems to prefer cool freshwater"	Patrick and Reimer, 1975
HAAR	*Hannaea arcus* (Ehr.) Patr.	Optimum pH 7.3-7.4; "cool, flowing water, particularly in mountainous regions"	Lowe, 1974; Patrick and Reimer, 1966
NIDI	*Nitzschia dissipata* (Kutz.) Grun.	Optimum pH 8.0; eutrophic; tolerates some salt	Lowe, 1974
NIFR	*Nitzschia frustulum* Kutz.	pH range 6.2-8.6; eutrophic; tolerates broad range of salt	Lowe, 1974
NIRO	*Nitzschia romana* Grun.	Unknown	
SYMI	*Synedra minuscula* Grun.	"Seems to prefer cool water"	Patrick and Reimer, 1966
SYUL	*Synedra ulna* (Nitz.) Ehr.	pH range 5.7-9.0; eutrophic; tolerates some salt	Lowe, 1974

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